(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 683 414 A1

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: 94303628.5

(51) Int. Cl.6: G02B 26/08

(22) Date of filing: 20.05.94

(43) Date of publication of application:
22.11.95 Bulletin 95/47

(84) Designated Contracting States:
DE ES FR GB SE

(71) Applicant: STATE OF ISRAEL - MINISTRY OF DEFENCE
Armament Development Authority,
Rafael,
P.O.B. 2250
Haifa 31021 (IL)

(72) Inventor: Netzer, Yishay
Yuvalim 112
20124 Israel (IL)
Inventor: Fraenkl, Efraim
20 Uziel Street,
Kiryat Motzkin 26332, (IL)

(74) Representative: Price, Paul Anthony King
D. Young & Co.,
21 New Fetter Lane
London EC4A 1DA (GB)

(54) **Optical scanning apparatus.**

(57) Scanning apparatus including a scanning mirror and a base, wherein the scanning mirror is pivotably mounted on a support which is linearly displaceable relative to the base. The scanning apparatus may also include a variable magnetic field source, mounted on the underside of the scanning mirror, and a fixed magnetic field source mounted on the base and arranged for electromagnetic interaction with the variable magnetic field emitter.

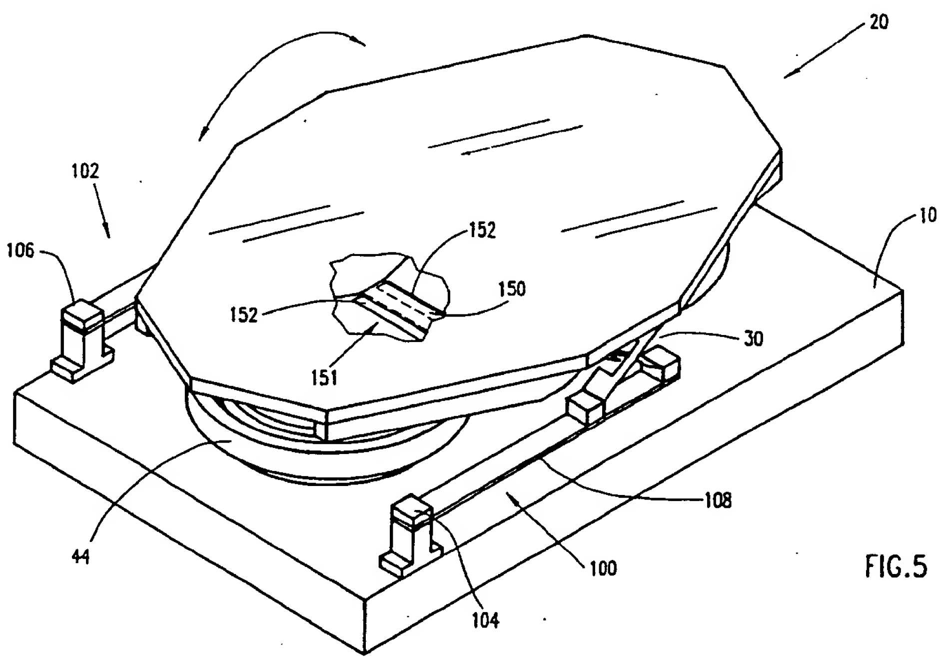

FIG.5

EP 0 683 414 A1

field emitter.

Additionally in accordance with a preferred embodiment of the present invention, the scanning apparatus further comprises a mirror position sensor, which provides as output first and second present position signals representative of the present position of the scanning mirror, and position control circuitry, which receives as input the present position signals and first and second command signals and which provides as output first and second new position signals representative of a new desired position for the scanning mirror.

Additionally in accordance with a preferred embodiment of the present invention, the variable magnetic field emitter comprises at least one coil, and the first and second new position signals energize the coil to generate the variable magnetic field.

Additionally in accordance with a preferred embodiment of the present invention, the scanning mirror is mounted on the linearly displaceable support via at least one pivotable assembly, the pivotable assembly comprising a plurality of electrically conductive, mutually isolated segments, and the first and second new position signals are transmitted to the coil via the at least one pivotable assembly.

In accordance with a preferred embodiment of the present invention, the mirror position sensor comprises a conductive element fixed to the mirror and first and second conductive elements fixed to the base, and the first and second present position signals are functionally related to the capacitance between the conductive element fixed to the mirror and the first and second conductive elements fixed to the base, respectively.

In accordance with a preferred embodiment of the present invention, the position control circuitry comprises apparatus for forming, from the first and second present position signals, a height independent value representative of the angular orientation of the scanning mirror relative to the base; apparatus for combining the value representative of the angular orientation with one of the command signals, to form the first new position signal; apparatus for forming, from the first and second present position signals, a tilt independent value representative of the height of the scanning mirror relative to the base from the first and second present position signals; and apparatus for combining the value representative of the height with the other of the command signals, to form the second new position signal.

There is further provided in accordance with a preferred embodiment of the present invention, scanning apparatus comprising a scanning mirror having a front reflecting surface and a back surface, a base spaced from the scanning mirror by a distance, electromagnetic apparatus for deflection of the scanning mirror comprising apparatus for providing angular deflection of the mirror surface with respect to the fixed base and apparatus for adjusting the distance of the scanning mirror from the base.

Additionally in accordance with a preferred embodiment of the present invention, the apparatus for adjusting the distance of the mirror surface from the base comprises at least one cantilever; and the apparatus for providing angular deflection of the mirror surface comprises at least one flexible pivot mounted on the cantilever.

In accordance with a preferred embodiment of the present invention, the electromagnetic apparatus further comprises capacitive apparatus for measuring the angular deflection of the mirror surface with respect to the fixed base, and for measuring the distance of the scanning mirror from the base, the capacitive apparatus comprising apparatus for sensing the change in capacitance between at least one conductive element fixed to the mirror and at least one conductive element fixed to the base.

In accordance with a preferred embodiment of the invention, the electromagnetic apparatus further comprises at least one magnet assembly mounted on the base, at least one coil mounted on the back surface of the scanning mirror, and apparatus for energizing the at least one coil.

In accordance with a preferred embodiment of the present invention, the scanning apparatus further comprises first and second magnet assemblies mounted on the base and first and second coils mounted on the back surface of the scanning mirror, positioned to interact with said first and second magnet assemblies respectively, when energized, wherein the apparatus for providing angular deflection of the mirror surface comprises apparatus for oppositely energizing the first and second coils, and the apparatus for adjusting the distance of the scanning mirror from the base comprises apparatus for identically energizing the first and second coils.

In accordance with a preferred embodiment of the present invention, the scanning apparatus further comprises first and second magnet assemblies mounted on the base, and first and second coils mounted on the back surface of the scanning mirror and positioned to interact with said first and second magnet assemblies, respectively, when energized; wherein the apparatus for providing angular deflection of the mirror surface comprises apparatus for providing a periodic, oppositely directed actuation of the first and second coils, and the apparatus for adjusting the distance of the scanning mirror from the base comprises apparatus for simultaneously providing a periodic, identically directed actuation to the first and second coils, wherein the period of the oppositely directed ac-

of cantilevers 100 and 102 decreases the amount of force necessary to displace arms 108 and 110, since the moment arm between mirror assembly 20 and end supports 104 and 106 of cantilevers 100 and 102, is increased.

Coils 24 and 26 interact with assemblies 12 and 14. Current in one direction in coils 24 and 26 causes them to be drawn toward assemblies 12 and 14, respectively, while current in the opposite direction causes coils 24 and 26 to move away from assemblies 12 and 14, respectively. If the currents in the two coils differ, the scanner tilts to the extent that the currents (and hence the forces) are unequal. Additionally, to the extent that the currents are identical and in the same direction, there is a net force up or down which causes deflection of arms 108 and 110 leading to vertical movement of mirror assembly 20. While a particular method of magnetically exerting a force on mirror assembly 20 has been described, it will be appreciated by those skilled in the art that other methods could be employed, for example, the methods described in applicant's Israel patent application serial no. 102,485, entitled "Scanning Apparatus".

As used herein, the term "currents in the same direction" (or "identically directed currents") shall mean currents which cause equal forces to be exerted on coils 24 and 26 in the same direction. It is these currents which cause vertical movement of the mirror. Also, "currents in the opposite direction" (or "oppositely directed currents") shall mean currents which cause equal forces to be exerted on coils 24 and 26 in opposite directions. It is these oppositely directed currents which cause the mirror to tilt.

For an arbitrary pair of currents I_{24} and I_{26} supplied to coils 24 and 26, respectively, the identically directed component equals $1/2 * (I_{24} + I_{26})$ and the oppositely directed component equals $1/2 * (I_{24} - I_{26})$.

The preferred apparatus for controlling the motion of substrate 21 relative to base 10 will now be described with reference to Figs. 5-9. As shown in Fig. 7, the preferred apparatus comprises a position control circuitry 122 which receives, from a sensor 124, two feedback signals v_{24} and v_{26} representative of the present position of substrate 21 relative to base 10. Position control circuitry 122 further receives a tilt command control signal over a line 126, representative of the desired change in the angular scanning position of substrate 21 relative to base 10, and a vertical command control signal over a line 128, representative of the desired change in the vertical position of substrate 21 relative to base 10.

In response to these four received signals, position control circuitry 122 outputs a first driving current to coil 24 over a line 114, and a second driving current to coil 26 over a line 116. Lines 114 and 116 each schematically represent one of the electrical connections available to coils 24 and 26 via conductive pivot assemblies 30 and 32. Coils 24 and 26 are further connected to ground via a line 118, which schematically represents a third of the electrical connections available via conductive pivot assemblies 30 and 32.

A first component of the driving currents provides currents in opposite directions to coils 24 and 26. As will be appreciated, opposite currents will cause equal and opposite forces to arise between coil 24 and magnet 40, and between coil 26 and magnet 42, which will in turn cause substrate 21 to pivot about pivot assemblies 30 and 32 until it reaches the equilibrium tilt position representative of this component.

Similarly, a second component of the driving currents provides currents in the same direction to coils 24 and 26. As will be appreciated, equal currents will cause equal forces to arise between coil 24 and magnet 40, and between coil 26 and magnet 42, which will in turn cause substrate 21 to move vertically until it reaches the equilibrium height above base 10 representative of the identically directed currents.

Reference is now made to Figs. 5, 6, and 8 which show a preferred embodiment of sensor 124. As shown in Figs. 5 and 6, sensor 124 includes a differential capacitor 151 comprising a plate 150 attached to the back side of substrate 21, and a split conducting plate 152 attached to base 10. When assembly 20 moves or tilts as described above, the capacitance between plate 150 and the respective portions of split plate 152 changes. This change in capacitance is measured by capacitance measurement circuitry, as, for example, the circuitry shown in Fig. 8.

As shown in Fig. 8, an oscillating voltage source 154 supplies a high frequency carrier signal to plate 150 via a line 118, which schematically represents the fourth electrical connection available on substrate 21 via conductive pivot assemblies 30 and 32. A pair of amplifiers 156 and 158 measures and amplifies the resulting modulated oscillating signals at the respective portions of split conducting plate 152, to form the two voltage signals v_{24} and v_{26}. The capacitance measurement circuitry shown in Fig. 8 can be located in any convenient location, for example, on base 10. While a particular method of capacitively measuring the position of mirror assembly 20 has been described, it will be appreciated by those skilled in the art that other methods could be employed, for example, the methods described in applicant's Israel patent application serial no. 102,485, entitled "Scanning Apparatus".

control circuitry 122 before scanning begins. Once set at the desired vertical position, feedback signals v_{24} and v_{26} will maintain scanner 204' at the new position, and the periodic vertical command signals received during the imaging of the target will induce vertical vibratory motion centered around the new position.

It will be appreciated by those skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. While a preferred embodiment for implementing the invention has been described, many other embodiments for implementing the invention will occur to those of ordinary skill upon reading this disclosure. Therefore, the scope of the present invention is defined only by the following claims.

Claims

1. Scanning apparatus, comprising:
   a scanning mirror; and
   a base,
   wherein the scanning mirror is pivotably mounted on a support which is linearly displaceable relative to the base.

2. The scanning apparatus of claim 1, further comprising:
   a variable magnetic field source, mounted on the underside of the scanning mirror; and
   a fixed magnetic field source, mounted on the base, and arranged for electromagnetic interaction with the variable magnetic field emitter.

3. The scanning apparatus of claim 2, further comprising:
   a mirror position sensor, which provides as output first and second present position signals representative of the present position of the scanning mirror; and
   position control circuitry, which receives as input the present position signals, and first and second command signals, and which provides as output first and second new position signals representative of a new desired position for the scanning mirror.

4. The scanner of claim 3, wherein the variable magnetic field emitter comprises at least one coil, and wherein the first and second new position signals energize the coil to generate the variable magnetic field.

5. The scanner according to either of claims 3 or 4, wherein the scanning mirror is mounted on the linearly displaceable support via at least one pivotable assembly, the pivotable assembly comprising a plurality of electrically conductive, mutually isolated segments,
   and whereas the first and second new position signals are transmitted to the variable magnetic field source via the at least one pivotable assembly.

6. The scanning apparatus according to any of claims 3-5, wherein the mirror position sensor comprises:
   a conductive element fixed to the mirror;
   first and second conductive elements fixed to the base;
   wherein the first and second present position signals are functionally related to the capacitance between the conductive element fixed to the mirror and the first and second conductive elements fixed to the base, respectively.

7. The scanning apparatus according to any of the claims 3-6, wherein the position control circuitry comprises:
   means for forming, from the first and second present position signals, a height independent value representative of the angular orientation of the scanning mirror relative to the base;
   means for combining the value representative of the angular orientation with one of the command signals, to form the first new position signal;
   means for forming, from the first and second position signals, a tilt independent value representative of the height of the scanning mirror relative to the base from the first and second present position signals; and
   means for combining the value representative of the height with the other of the command signals, to form the second new position signal.

8. Scanning apparatus, comprising:
   a scanning mirror having a front reflecting surface and a back surface;
   a base spaced from the scanning mirror by a distance;
   electromagnetic apparatus for deflection of the scanning mirror comprising:
   means for providing angular deflection of the mirror surface with respect to the fixed base; and
   means for adjusting the distance of the scanning mirror from the base.

9. The scanning apparatus of claim 8, wherein:
   the means for adjusting the distance of the

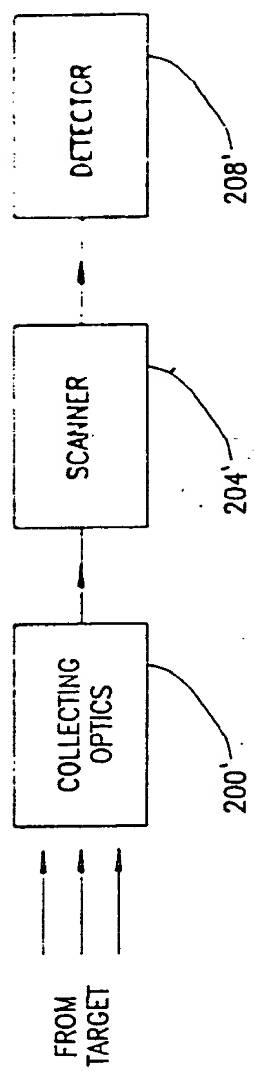

FIG.2

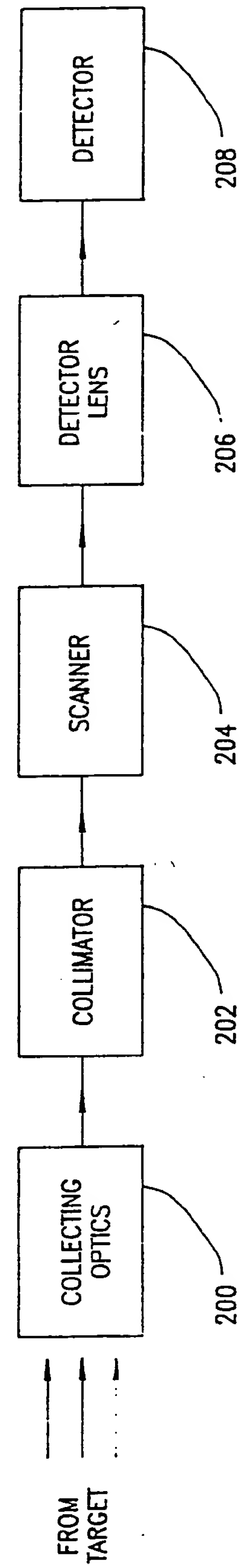

FIG.1
PRIOR ART

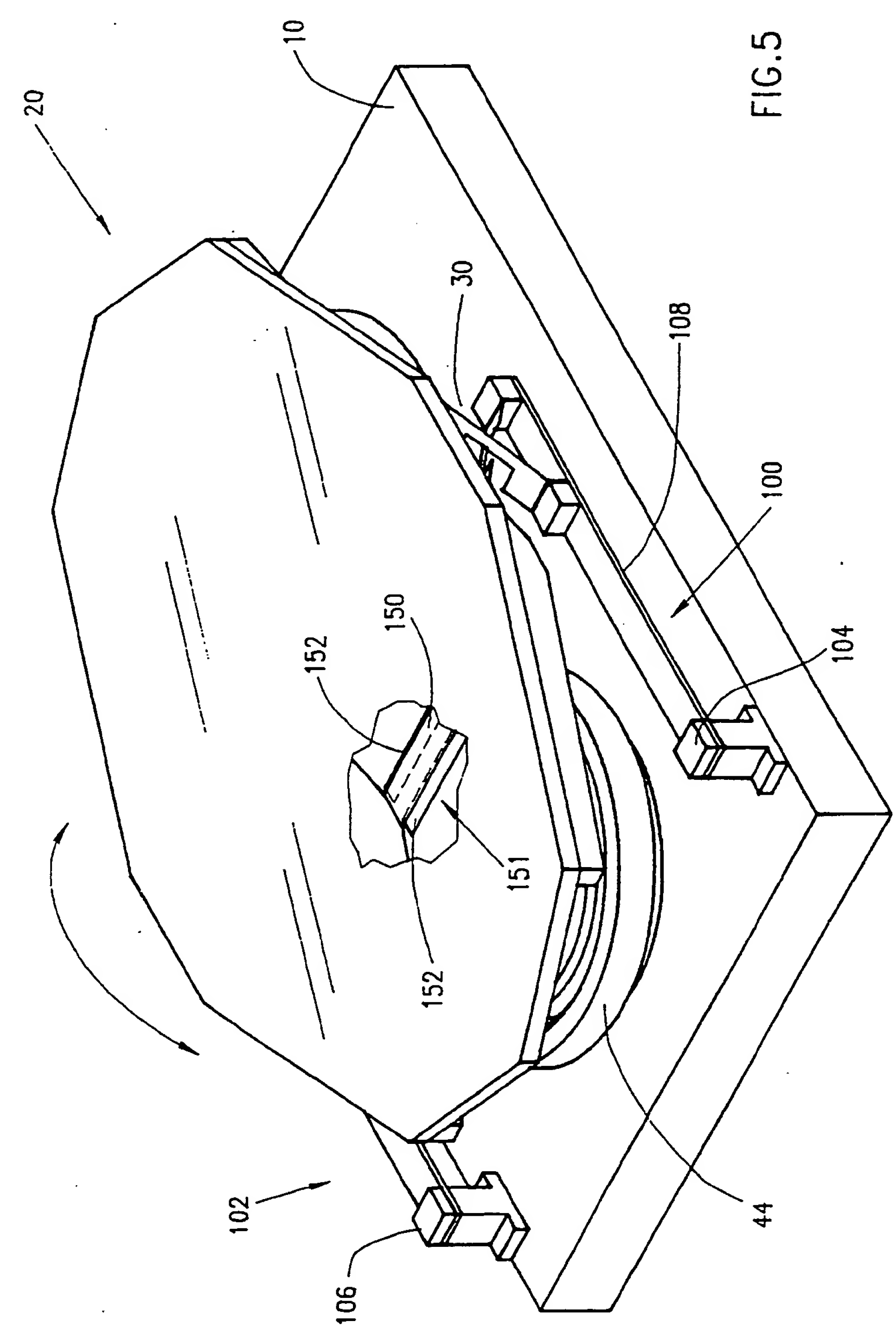

FIG.5

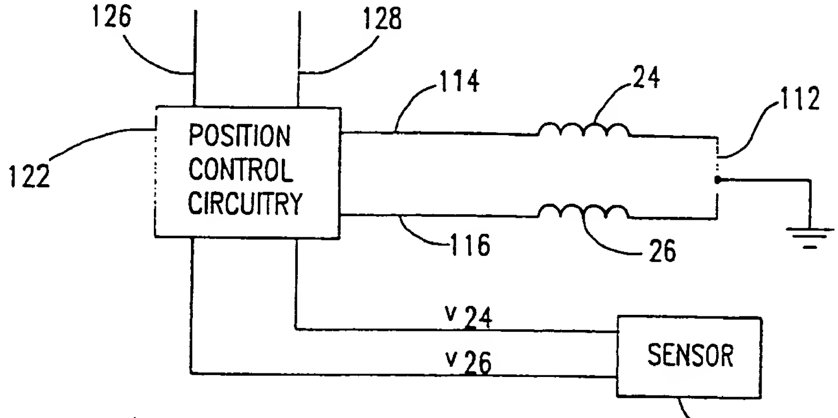
126
128
114
24
112
122
POSITION
CONTROL
CIRCUITRY
116
26
V 24
V 26
SENSOR
124

FIG.7

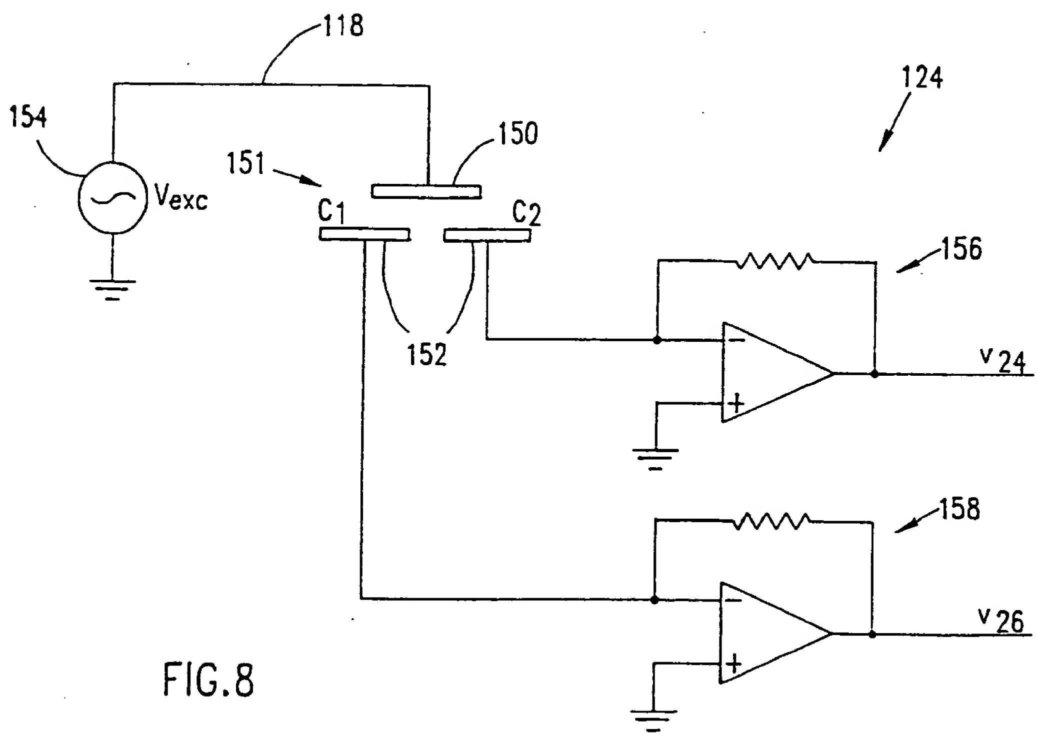
118
124
154
150
151
Vexc
C1
C2
156
152
V 24
158
V 26

FIG.8

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 30 3628

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	FR-A-1 362 282 (FARRINGTON ELECTRONICS INCORPORATED) * page 2, line 26 - line 41 *	1,15	G02B26/08
Y		2-4,6,8,10,11	
A		5,7,12-14	

X	CA-A-1 163 299 (NORTHERM TELECOM LIMITED) * page 3, line 3 - line 14 * * page 9, line 12 - line 14 *	1,15	

X	US-A-3 797 908 (WARD ET AL.) * column 1, line 12 - line 24 *	1,15	

D,Y	EP-A-0 579 471 (STATE OF ISRAEL MINISTRY OF DEFENCE) * the whole document *	2-4,6,8,10,11	
D,A		5,7,12-14	
	-----		TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			G02B H04N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	23 August 1994	Bequet, T

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document